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MARINE

AND

NAVAL ARCHITECTURE,

OR

The Science of Ship Building,

CONDENSED INTO A SINGLE LECTURE,

AND

DELIVERED BEFORE THE SHIPWRIGHTS OF THE CITY OF NEW-YORK,

In the Rooms of the American Institute,

September 20th, 1844.

BY JOHN W. GRIFFITHS.

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MARINE AND NAVAL ARCHITECTURE.

GENTLEMEN—

In again coming to the rostrum, it is perhaps quite unnecessary that I should reiterate the causes that impelled me on former occasions to pursue a similar course, having been led to suppose that the erroneous opinions formed by practical men upon the theory then introduced, were consequent upon its being laid down in detached portions; hence it will appear manifest, that I should endeavour to accomplish at a single effort, what I then laboured to perform at sundry times, if I would successfully define the counter position in which I have been placed. It is for this purpose that I have again ventured to launch my frail bark, not upon the turgid waters of precedent, but upon the dark mountain-crested billows of prejudice, and if the casual circumstances that have thus thrown me upon this tremulous ocean of science, shall serve to arrest the attention of those whose interests are closely allied to the commercial interest of our country, I have a reward paramount to the labour performed, having no soaring ambition to gratify, no vindictive feelings to revenge. Seeing that systems are sometimes despised because they are not known, and not known because they are despised, we are irresistibly brought to the conclusion, that no system is worth anything that is not worth carrying out, and that a system cannot be carried out before it is known. In connecting science with practice in this complicated art, my theorems must of necessity come in collision with the practice of the age, hence the necessity of limitation to my remarks upon the discrepancies of the art, and of forbearance on the part of my audience. But that arrangement, that skill necessary in making all the parts of a continued *process* tend to a result in which the truth is clearly and firmly established, cannot be expected from one who has devoted but the relaxing hours from toil in the defence of science in contradistinction with the practice of the age. The mind, like the body, acquires strength by exertion; the art of reasoning, like other arts, is learned by practice; and he who has passed over the ground superficially, will find that the obstructions to his future progress are yet to be removed.

The science of ship building has long been shackled with deep rooted prejudices. In all ages this has been regarded as an abstruce science; precedent has been its watchword, rather than cause and effect; and as a consequence, the commercial world have become wedded to old habits, and few there are who make any advancement beyond the path their fathers trod. But shall this fixedness of mind hold us in a state of eternal childhood? Shall not this great theatre of nature *arouse* us to those bold researches in which science engages with such keen delight? Although the ocean, from an antiquity more remote than profane history can trace, has been navigated by man, yet we have no evidence that the first principles of ship-building were understood

by the ancients, but it is plain that they were not then, or even now understood. The limits of a single lecture does not give scope enough to delineate the progress of improvements in this important art during the early ages of commercial history.

It is to commerce we owe a debt of gratitude for the boon of civilization, by which the amplest openings have been afforded to commercial activity, and numberless valuable productions have been laid under contribution to the insatiable luxury of man. During the early ages, as at this age of improvement, commerce was regarded as the legitimate offspring of agriculture, and ever has been the talisman that has raised man from the condition of the savage. It is commerce that has given us abundance, comfort, and elegance, instead of want, misery, and barbarism. By this mutual intercourse, the gifts of science and art, as well as those of nature, are distributed alike to all. Commerce is the great engine by which the blessings of civilization are diffused throughout the world, and is the only effectual barrier to the avaricious grasp of monopoly.

When we compare the ships of the nineteenth century with those built during the dark ages, when architectural science was rude and uncouth, when discoveries on this subject were so acceptable to mankind, that inventions tending to the improvement of the art of ship building, were deemed worthy of the greatest honors, we are almost ready to exclaim that the progress of this science has already outstripped the improvements of this improving age; but when we weigh our boasted attainments in the balance of utility, when we arraign our improvements at the bar of first principles, they dwindle into insignificance, and we are irresistibly brought to the *threshold* of an inquiry into the various causes producing such deleterious effects; but precedent asserts her prerogative, and we are again thrown back in the track our fathers trod. It is a subject of irresistible interest, and would seem to demand the most ingenious research, to give a graphic description of the ships in early ages.

It is not a part of my province to induct my audience into the glory of that commerce that civilizes the world, amid the smouldering portals of antiquated cities, like Tyre or ancient Sidon, whose once spacious palaces have either been supplanted by miserable hovels, or become the lair of beasts, whose vaulted cellars that were once the storehouses of the treasures of the world, have become the abodes of indigence, leaving scarce a vestige by which to tell what were the advantages of commerce to the mother of Phœnician cities. I fain would pause and take a fanciful glance at the ship Argo, when on her fabled Argonautic expedition to Cholcis after the golden fleece of Phryxus, or fathom back a distance in the vista of time, only commensurate with the history of this republic, and lingering over the cradled infancy of my country, to scan with eager eye the May-Flower, that favoured car of Neptune, that conveyed the pilgrim fathers to this western world. *But*, however congenial those themes may be, my brief space forbids their pursuit. It must not be supposed that ships in early ages had three masts, or that they were of a size corresponding to the name; from fifty to sixty tons by measurement was considered very large for a merchant ship, and they were managed with sails upon only one mast. The Phœnicians are said to have been the first inventors of the art of sailing, and the sails first used, seem to have been made of skins. Row galleys, or vessels of war, had no masts, but were managed with oars, their sides forming an angle with the surface of the water, of about forty-five degrees, so as to enable them to apply a great number of oars, by

having several banks, or tiers above each other; the lower tier being short, and each successive tier longer, than the one below. They were built longer than the merchant vessel, that they might sail faster. Ship building was introduced into Rome about 417 years before the *Christian Era*, and seems to have well suited the ambition of that warlike people; we find however, that but little improvement was made either in the model, or management of vessels for several centuries. The Anglo Saxons built rude and frail shallops in the middle of the fifth century. And in the beginning of the tenth century, in the reign of Alfred, the founder of the English monarchy, a Northumbrian free-booter discovered that by building his ships longer, he could increase their speed with the same displacement, and thus elude the vigilance of that energetic monarch; but it was reserved for the fifteenth century in which to make one grand and successful effort to improve this important art. During this century the Great Harry, a ship of about five hundred tons by admeasurement was built, and was doubtless the first vessel that had three masts. The invention of having the topmast moveable at pleasure, was discovered during this century.

The Parsees of India, who migrated to the Island of Ormuz, in the Persian Empire, to escape the rigours of Mahomedanism in the beginning of the same century, practised the art of ship building with success, causing that once barren rock to become one vast storehouse, teeming with the productions of the East.

It was during the fifteenth century that ship building received an impulse from which we may cherish the hope that it will never recede. About the year 1603, the commercial world became indebted to Phineas Pett, of England, for many improvements connected with the art of ship building, being doubtless the ablest naval architect of that, or any former age. It was by him, convex lines were introduced on the immersed part of all vessels. The studding sail and sprit-sail were also invented by him. In Europe the science of ship building seems to have been encouraged by the governments, under which the art flourished in various ways, hence we find laws enacted in accordance with the true spirit of the age. I fain would say as much at least of my native land, but truth bids me forbear.

Our government by enacting laws so detrimental to commerce, deprives itself of that aid so essential in case of a rupture with a foreign power. These splendid European packets, the pride of this commercial metropolis, and of these United States, might have been the bulwarks of her defence. Our merchant ships are superior in many respects to those of our navy, and were it not for their disproportionate principal dimensions, they would be far better suited for the purpose of *war*, than three quarters of the ships of which the United States navy is composed. Our ruinous tonnage laws have a direct bearing on the dimensions of every ship that is built in the United States having more than one deck. But ship owners proceed with caution, that the magnitude of the mischief may not provoke *national legislation*, and thus *avarice* is permitted to *riot* without *control*. The science of ship building is not indebted to our government, for any improvements that may have been made, but it is maritime enterprise that has achieved all that has been done in *America*. The onerous burdens entailed upon commerce in consequence of the eixsting tonnage laws, have done much to retard the progress of science. The merchant finds it to his advantage to have his ship built deeper, and narrower than she should be, notwithstanding, as a consequence he may be

compelled to carry in his ship from one to two hundred tons of ballast, more than he would otherwise find it necessary to carry, in order that she may possess the required stability, without which she would be totally unfit as I shall hereafter show, for the purpose intended. To what extent the abridgment of human life is consequent upon avarice, heaven alone can tell; but certain it is, that to make the tonnage laws what they should be, would be to set a higher estimate upon the lives of confiding passengers, and of those whose home is on the deep. The watchword of this science would then be upward and onward, until we should be able from the proud *eminence*, to look forward and be hold an approaching *era*, in which the ship, this mistress of the *ocean*, would be for all the purposes for which she was intended, second only to heaven's last best gift to *man*. Next to our unjust tonnage laws, the mechanic is enslaved by ancient traditions and hoary prejudices. Here is the mighty screw and lever that binds him down. The mind, that *great* pharos of *intellect; thought*, that sublime machine, does not preserve its equilibrium, and consequently cannot maintain its activity, being fettered by public opinion. Not that *noble public opinion* that gives hardihood and unshrinking fearlessness, but that wayward offspring of fashion and fear, that intolerant public opinion which weighs actions by their popularity, and not by their effects, which bids us do that which is customary, rather than that which is right; a dishonest time-serving sycophancy, that is like an incubus upon our boldest thoughts, and best exertions, making cowards of the brave, and checking the spread of knowledge, that darkens both land and sea with its prejudices, and chills the heart with its cold decrees, deeming him an addle-pated enthusiast who dares to assert by precept or practice, that the fields of science are open alike to all. The prejudices iterwoven with the present system of ship building, cling to the builder like the poisonous ivy to the monarch of the wood, throwing fetters of bondage around his intellect, which if not rent assunder, will cause him like the oak, to perish in its palsying embrace. I date the decline in the progress of this science (if not in every other) from the time the operative mechanics cease to study its principles, and although the ship builder may set a low estimate upon the experience of the operative mechanic, yet I have little hesitation in saying that he has advantages within his reach, that the builder does not possess.

The art of ship building has ever been considered as a branch of mathematics, and although intimately connected with that beautiful science, it has in every age proved a barrier to the scrutiny of scientific men, although calculations by figures is the most certain guide to truth, and when properly balanced, will lead to inevitable results; yet in this science there are abstract questions beyond the grasp of mathematicians; on the other hand, practice without science is equally dark; experience is not the grand palladium of success in this complicated art, but when scientific reasons can be assigned for advantages which are the result of common practice, they tend to satisfy the mind, and impart a pleasure in the prosecution of our labours, and although no fragment now remains, no relic now extant but such as may be gleaned from the page of history, to show what ship building has been, or to guide the genius of modern times, we are not the less inexcusible for shutting out the light of science from this important art, upon which is based our commercial, and as a consequence in a great measure, our national prosperity. Without entering upon any disquisition to show what have been the results of science, or of practice in the abstract, it not being the time or place to recount the miserable failures

in ship building, they are however but the *index* of destiny, and will continue so to be until *guess* work is abolished from the art.

In the study of a science, it is requisite first to become familiar with the peculiar properties the elements possess we are about to explore, in this manner difficulties that at first seemed insurmountable, will yield as we advance, and in this manner also we shall find that nature's laws that at first seemed the most incongruous, are exactly suited to the wants of man, and without the aid of which he would be deprived not only of the advantages of commerce, but of sundry other most important blessings. Water being a non-elastic fluid, enables us to arrive at the amount of resistance met by vessels of different models; a body moving through a fluid having no elasticity, a ship for example, loses just the amount of motion, and no more than the fluid gains, hence we have this hypothesis, that to find the mean amount of motion the fluid acquires at a given speed, is to find the amount of resistance to be counteracted at a corresponding speed; again, we find the amount of motion to be small acquired by the fluid on the anterior part of many of our steam boats of recent build, the angle of their line of flotation being so acute that there is no wave generated at a speed perhaps of twenty miles per hour, showing conclusively that the resistance is less than 2160 lbs. per square foot, or less than the atmospheric pressure upon the surface of the fluid. But again, although one element possesses no elasticity, being incompressible, we are thereby enabled to determine the amount of resistance to be overcome. The elasticity of the wind does not prevent us from determining the amount of power or area of canvass necessary to augment that power, until it shall be sufficient at a given speed to counteract the resistance to be thus overcome. Many scientific men have laboured to show that the resistance met by vessels, arising from a collision with the wind, should be calculated in accordance with the laws governing the motion of projectiles; *but* upon a careful investigation, that illusion of the fancy is at once dispelled. The direction of projectiles is not horizontal; being every instant influenced by the action of gravity, while on the vessel the demands of gravity having been satisfied by the fluid that sustains her, the result of which is that her longitudinal direction is always horizontal.

It must, and doubtless will be conceded upon the broad basis of mathematical reasoning, that the science of marine and naval architecture should be based upon the equilibrium of fluids, which should teach us more than our daily practice is wont to teach, by adhering to the present mode of modelling ships according to the peculiar notions of builders, without any regard to those principles furnished by nature, by the application of which we may test the models of our ships, we exhibit a manifest weakness unworthy of mechanics, and a blind prejudice to precedent, unworthy of men possessing an ordinary share of intelligence. Taking the equilibrium of fluids for our text book, *what* do we *learn*? may I not say what do we not learn! are we not brought irresistibly to the conclusion that the breadths at the several water lines, as exhibited on the transversed sections of the two body plans, should bear the same ratio to each other, that they do at the greatest transverse section.

In all questions embracing an algebraic form, it is essential that we should assume proportions upon which we can base our calculations, and from which we may arrive at inevitable results; thus, assuming the greatest transverse section to be of such form as we desire, and the load water line to be formed as our judgment would dictate; also, assuming the number of water lines to

be six, including load line, and setting that line down at 100 per cent, the fifth at 95 per cent, the fourth at 90, the third at 80, the second at 68, and the first at 48 per cent, does it not follow that on every transverse section below load line, the several water lines should be so proportioned, and does it not also necessarily follow that the ship, modelled upon such principles would, with the same amount of displacement, meet with much less resistance from the fluid to which her model is thus adapted. It is strange indeed, if *proportion*, that great principle in mechanics, the grand palladium of success in mechanism, should find no resting place in the art of ship building; the fact is humiliating indeed, that a great and perhaps the greatest intellectual art in the catalogue, should possess so little of that quintesence of beauty as is manifested in the modelling of our ships, both in those of our navy and merchant marine. If we will but look abroad on the works of nature, we will find that proportion is the rallying watchword; we will see it stamped on all her works, from the glow worm that lights our path, to the rain bow that spans the heavens. The ocean, upon which those stupendous fabrics are made to perform their trackless evolutions, exhibit the same principles of proportion; the science of hydrostatics, or the equilibrium of fluids, teach us the operation of those laws that so harmoniously blend its component parts. Proportion is to the mechanic, especially to the shipwright, what the fulcrum is to the lever, or the axle to the pulley. As well might the Chinaman talk of the beauty of his junk, as for Americans to boast of the beauty of their ships, unless proportion has been the governing principle in their construction; beauty without proportion is all a farce, proportion is the standard by which we may weigh our attainments or measure our improvements. The French rhetoricians have a maxim which affirms, that there is nothing beautiful that is not true. It is not true that the ship builders of the nineteenth century, laden as they are with the prejudices of their ancestors, and governed by no standard of proportion, can model their ships with a rigid adherence to the purposes of utility. But to construct a ship upon scientific principles, is not only to so adapt the form to the fluid that the resistance to be overcome will be the smallest amount commensurate with the displacement, but it is to so arrange the material of construction that the greatest amount of strength may be obtained; this important result cannot be gained while the present practice is adhered to, of framing by diagonal lines, inasmuch as the greatest amount of burthen to be borne must be sustained by the weaker part of the ship, and no sophistry can make that right which common sense pronounces wrong; and may it not be justly said of the man who constructs a ship upon scientific principles, that he has achieved a greater triumph than was gained on the fields of Marengo or the plains of Waterloo.

This science, unlike most others, in possessing none of those relics of ancient skill to guide the genius of modern times. The remnants of ancient mechanism crumble into dust only with the weight of centuries, and then are taken from the earth with the fossil of antiquity. But where are the monuments reared, to point generations yet unborn, to the skill of naval Architects? No towering pyramids, no massive columns, point to the skill of their ancestors; the chisel of the sculptor, the pencil of the artist, have never been exerted, to show in after ages what ship building was in the days of our sires. Nought remains above the wide spread ocean to show the form of that engine of war, or that messenger of peace, but the musty faded sheet. The voracious jaws of our mother earth has yielded no spot to do honour to naval architects, and thus the mantle of *oblivion* is thrown over the discrepancies

in the art, and the ocean has swallowed up millions of our race, until it has become one great *charnel* house, and the waves are but its tomb stones. I will not dwell longer on the reminiscence of the past. It is, my audience, by the introduction of true science into the art of ship building, that greater security will be rendered to human life. The basis upon which this science rests may be divided into three grand divisions, all working harmoniously, and in perfect unison with the laws of nature, and each in itself of sufficient importance to abrogate the successful operation, and the combined efforts of the rest; to what extent those divisions have a bearing on the art, I will now invite your attention; stability, capacity, and velocity are the requisite properties when properly balanced, that form the perfect ship; upon the stability of vessels or their tendency to preserve an equilibrium when heavily pressed on one side by the wind upon their sails, I shall first descant.

There are two kinds of stability, natural and artificial, which in all vessels is consequent upon their principal dimensions, or their length, breadth, and depth, inasmuch as the centre of absolute gravity must be lower than the centre of displacement, or there is no stability, the vessel would be quite as likely to float on one side as in an upright position, and it is this unerring law of nature that compels the ship owner to carry several hundred tons of ballast in his ship more than he would have carried had his ship been of a breadth proportionate to her depth; although the centre of absolute gravity must be located at a point below the centre of displacement in all vessels, to keep them in an upright position, it does not necessarily follow that the centre of displacement or of absolute gravity will in all vessels displacing an equal bulk of water, be found at the same point either perpendicularly or longitudinally, neither does it follow that the centre of absolute gravity is in the centre of the ship in any sense, or that the centre of displacement is equidistant from the extremities of the water displaced; the centre of absolute gravity is the point upon which, if the ship were suspended, she would equipoise; the centre of displacement is also that point upon which if the fluid displaced possessed the same form as the immersed portion of the vessel, and were thus congealed and suspended, the point upon which it would be bound to equiponderate would be the centre of displacement. There is another kind of gravity, but as it does not often effect the stability of vessels, I shall show its bearing in its proper place.

A body being placed on a fluid specifically heavier than itself, will sink so far that the weight of the fluid displaced is equal to the whole weight of the body; and when it assumes the position of equilibrium, the line which joins the centre of gravity of the body and the centre of displacement (which is the same as the centre of gravity of the immersed part supposed to be homogeneous) is perpendicular to the surface of the water, or the horizon. The centre of gravity of a body is a fixed point as far as it regards the body itself; but the centre of displacement, which depends on the figure or form of the immersed part, will change its place when the form of the immersed part undergoes any alteration. It is on the relative situation of the centres of gravity and of displacement that the character of the equilibrium of floating bodies depend; namely, whether it is stable, unstable, or indifferent. If the form of a body or vessel be such, that on pressing it on one side from a position of rest, its centre of gravity takes a higher position, the body has a tendency to redress itself, the equilibrium is stable. On the contrary, if by a slight change of situation the centre of gravity occupies a lower place, the body will

not return to the position of equilibrium, but will be upset. In this case the equilibrium is unstable; but a body may be so constituted (for example a cylinder floating with its axis horizontal) that in every position the centre of gravity and of displacement are in the same vertical line, in this case the equilibrium cannot be disturbed, and may be considered the equilibrium of indifference, the body having no tendency to maintain one position more than another; were a body or vessel of such form, to acquire stability enough to maintain one position more than another, it would be such as I have already denominated *artificial*. As the stability of all floating bodies depend on the height of the centre of displacement above the centre of gravity, vessels should be so constructed (I allude now to the materials and manner of construction, and not to the form,) that the centre of gravity of the whole mass shall be at the lowest possible point. When a vessel is without cargo or ballast, the weight of the masts, rigging, and sails, raises the centre of gravity to such a height as to render the equilibrium unstable, or at least its stability is so small that it cannot be safely subjected to the ordinary pressure on the sails necessary to give motion, and consequently would be altogether incapable of encountering a gale or a heavy sea. Although the stability of floating bodies depend almost entirely on their form, it does not necessarily follow that the stability of a ship is the result of her form farther than her form is the result of her dimensions; for example the, immersed part of two ships may be of the same form and size if you please, and one possesses a greater degree of stability than the other in consequence of her having less depth, thus concentrating the centre of weight or of absolute gravity at a point lower than in the deep ship, again the specific gravity of the materials and particularly the spars, may not have been the same in both ships, which would materially effect the stability of the one having spars of the greatest density. Many ship owners, and not a few builders, suppose by creating an artificial stability with the aid of ballast, that the ship is quite as safe at sea as if she possessed an equal degree of natural stability; to what extent this opinion would prevail, were it not on the side of interest, let my audience judge, having no desire to abridge their prerogative, and being well satisfied that they should attain that celebrity which nature only concedes to practice. The motions when at sea, of a ship relying upon an artificial stability for support, are uneasy, irregular, and consequently have a tendency to strain the whole fabric. That I may be better enabled to show to what extent men's judgment in this matter, based upon extended experience, are warped by dollars and cents, I will show the result of measuring a ship by the existing tonnage laws. First it will be necessary to assume the dimensions and displacement of a ship, assuming also the proportionate dimensions, to be what they would be, were our laws in accordance with dictates of justice. Setting down the length of the ship at 178 feet, breadth of beam 42 feet, and depth of hold 21 feet, and assuming the ship to be flat, the displacement would be about 3200 tons below the greatest immersed line of flotation or load water line, which would be precisely the weight of the ship when loaded to that line; we will set down the weight of the ship at 1600 tons, thus leaving a balance of 1600 tons for cargo, provisions, &c., now let us measure this ship by the tonnage laws of the United States, and the result is found to equal 1652 tons, which approximates near the truth, and enables us to form a more favourable opinion of the correctness of the principles upon which the existing laws were based; the law as it now exists, accounts one half of the breadth of beam for the depth of hold, which by the assumed dimensions,

would differ but little from the actual displacement after the weight of the ship was deducted. But although the above assumed proportions would, as far as they were concerned, make a safe ship, they differ widely from the proportions of our merchant ships; the object is to build them as narrow as possible, and at the same time to retain all the depth they possibly can. A ship of the length and depth already assumed, would have but 36 feet beam, and consequently but 18 feet would be accounted for the depth of hold, thus leaving 3 feet of unmeasured depth; the result is, the tonnage is registered at 1214 tons, leaving a balance of 438 tons not registered.

By the laws of France, the registered tonnage of the dimensions already assumed, would be 1352 tons. In Russia, and in England under theo ld law, it would be the same as in the United States. In Naples it would be set down at 1671 tons. The laws of most other commercial nations, call for measurements at different places, by which method the tonnage and displacement differ but little. England abolished her old tonnage laws in January, 1836, being clearly convinced that they were founded on erroneous principles, and led to the most mischievous consequences; under this pernicious system vessels were built narrow and deep, and thus not only inefficient, but highly dangerous. By the new method, the relative capacities of ships are determined within four or five per cent, though in extreme cases the difference may amount to ten per cent from her actual displacement. By the new method, the dues paid on tonnage are proportioned to the capacities of the vessels; and as no advantage is gained in these respects by defective models consequent upon disproportionate dimensions, a marked improvement in English merchant vessels has followed the passing of the bill of '36. They possess more stability with less ballast. I am aware that it is held as *an axiom* by those whose experience give their opinions weight in the commercial world, that the stability of a ship is in as great a degree the result of her form, as it is the result of her dimensions. But I have yet to learn, that by increasing the displacement, while the principal dimensions and the draught of water are the same, that the stability is materially effected. The dimensions of a ship, and the form of her lines are questions of different import. If a ship-builder were asked if a ship of 160 feet keel, 35 feet beam, and 21 feet hold, with spars of the usual size, would stand up without ballast, would he hesitate and inquire what was to be the form of her lines, before he would decide? I am persuaded he would not.

Perhaps the following exposition will serve to illustrate the principles upon which the stability of all vessels depend, better than any other that I could adduce. Assuming that a sloop of war is built by such dimensions as would render her stability precarious, and in arranging her armament, we will place her guns in her hold, that we may thus secure an upright position. While thus freighted, we will find the two central points of gravity, and that of displacement; and having marked their location, we will now proceed to remove the guns upon deck—in the performance of which, we will perceive that the stability gradually diminishes, and doubtless before the guns are all removed upon deck, it will be found necessary to make use of precautionary measures to maintain the position already assumed. Under such circumstances, is it not plain that the centre of displacement has remained stationery, that the ship weighs the same now that she did when the guns were in the hold, consequently displaces the same bulk of fluid. It is the change of location that has taken place in the centre of the absolute gravity that causes this instabili-

ty; the centre of the weight has been elevated by the transposition in the location of her guns. A question at once arises, what change in the structure would be necessary to remedy this discrepancy, or this want of stability?—Would the principles of construction, so strenuously advocated by the zealots of the present mode, ensure success; would an increase of the depth, or an increased displacement at the extremities of the line of flotation remedy the evil? I answer, No Sirs!

Have we not already seen that by elevating the centre of gravity, we diminished the stability, and does not an increase of depth elevate that point? Would it not better accord with the principles of philosophy, to increase the breadth, or diminish the depth, and thus cause the centre of gravity to descend below the centre of displacement.

My inclination leads me to a further consideration of this subject, but my limited space admonishes me that I must bring my remarks upon this part of the science to a close.

Among other considerations that should arrest the attention of marine architects, the buoyancy or displacement of his ship should claim his attention. To increase the displacement of a ship, is to increase her buoyancy, hence the necessity of knowing the weight to be sustained when modelling a vessel. The displacement of all vessels is exactly equal to the entire weight of the vessel and all on board. It matters not how great or small the bulk of the cargo may be, this axiom holds good at every line of flotation—it is one of nature's unerring laws, wisely ordered as a check upon the avarice of man. In a fluid more dense, the vessel displaces less, and if the fluid be less dense, the vessel displaces more; but in all cases the weight of the vessel and the bulk of water displaced, weigh precisely the same when the fluid is in a state of rest; but it does not follow that a bulk of water of less magnitude than that displaced, would not, under any circumstance float the vessel. A sheet of water of half an inch in thickness will as effectually float the largest ship as the ocean itself; and abundant proof may be afforded of the truth of this seeming paradox, at almost every wharf in this commercial metropolis. A vessel may be seen at a wharf preserving an equilibrium, with a small sheet of water on one side, and the river's whole breadth on the other; and we find as little difficulty in moving the vessel from the wharf as to it, when not affected by tides or currents Without this equilibrium of the fluid, upon which our commercial wealth depends, the ocean would be but a wide waste, and of no service to man; vessels might be built but they could never be sent to sea; the preponderating power of the ocean, pressing as it undoubtedly would upon every shore, and upon every river and outlet, would forever lock every vessel to its native shore. The star-spangled banner that now waves in every clime, would no longer be seen abroad.

Much more than is generally supposed depends upon the buoyancy of vessels; the strength as well as the velocity of all vessels, is in a great degree consequent upon their displacement. A vessel may have a sufficient displacement to sustain the required weight, and yet have it so arranged that she will be neither a strong nor a fast sailing vessel. Two vessels may be built by the same principle dimensions or of the same length, breadth and depth, and one more burthensome than the other, by 40 per cent., or capable of displacing the most water by 40 per cent., and yet the vessel displacing the most water, or carrying the greatest burthen, may sail much faster than the other. This striking contrast is principally owing to an improper distribution of the

buoyancy on the sharp vessel, or the relative gravity of the immersed part of the vessel. All floating bodies have a natural position or line of flotation, in other words they possess gravity in proportion to the matter they contain, hence the necessity of constructing the part of the hull above water, proportionate to the buoyancy below, so that were the vessel cut into transverse sections, each section would float at the same line of flotation as before, or that there would be a displacement in each section, corresponding to the entire weight of that section. This can only be accomplished by separating the part of the model above the line of flotation from the immersed part, or that below. But although the strength of the ship would seem to call for such arrangements in the structure, the purposes of convenience, comfort, and utility, compel us to depart in some measure from its adoption in that part of the hull above the greatest immersed line of flotation, the overburdening effects of which may be counteracted by other means. But this departure from first *principles* in the construction of the ship above water, would not diminish her speed, provided she was brought to her natural position or sailing trim, which is *not* as is generally supposed the line of flotation when launched, the rake of the stern and spread of the buttocks is not proportioned to the buoyancy below; in other words they do not bear the same proportion to each other that the bow and its sustaining part below does, consequently when the vessel is launched, she draws more water aft than is required to bring her to her natural position, and as a consequence to her best sailing line of flotation, unless the model be separated at the line of flotation, an error in the relative gravity of the ship is unavoidable; and while that part of the model above the greatest immersed line of flotation should be attached to the model as a model, and for the purposes of measuring length, breadth, depth, &c., the immersed part is the only part requisite for calculating the displacement and centre of relative gravity of a ship. The principles upon which ships have been built in the United States, for the last thirty years, would not have justified any builder in hazarding his reputation professionally, by building ships upon scientific principles, and having pursued the present course until their eye has become familiarized with the present or similar forms; they have lost sight of the grand design in the construction of this stupendous fabric. Hence the reason why every improvement is repudiated in building ships, but that of price. The original design in building ships may be expressed in one short sentence, and it matters not what the ultimate object may be, profit or pleasure, it does not qualify the sentence, *fitness* for the *purpose*, and *proportion* to *effect*, the *object designed*. And what is the object designed? Is it not to build ships that will carry the largest cargo with the smallest amount of registered tonnage, and to make their voyages in the shortest possible time, and if a combination of these qualities be the object in view in ship building, even as at present practiced, I say without fear of successful contradiction, that *guess work* never can compete with science. Experience unaided by genuine science, may, and frequently does lead to useful improvements, while the progress of such improvements is generally slow, indirect and frequently unsatisfactory. But when scientific reasons can be assigned for the advantages which are the result of common practice, they tend to satisfy the mind, and impart a pleasure in the prosecution of our labours.

There are certain particular principles attached to every art on which its theory is founded; these principles must be found to depend on certain truths, which recognized by every one, and indisputable, oblige the mind to concur

in the deductions that result from them. In applying these truths to the art of shipbuilding, it must be conceded that ships are not built in accordance with such principles as would ensure their success, the shadow has been mistaken for the substance, and while we pride ourselves in the beauty of our ships, we have forgotten that they do not sail as fast as those of our sires. But we are told that the general averaged length of voyages is one-third less than they were thirty years ago. I *admit it*, but what does it prove ; to me it is conclusive evidence that while we have been slumbering, the hardy sons of *Neptune* have won to themselves lasting laurels to which our ship builders have no just claim. When we boast of the number of short voyages being trebled, we must not forget that the nnmber of ships have been more than quadrupled.

We sometimes are shown a ship that seems to be the *beau ideal* of perfection, but who can tell the cause of her sailing so fast, or of her working so well ; is it because the spars are in accordance with first principles or concentrate the power at the same point with the pressure on the hull ? in other words, does the centre of the relative gravity and the centre of the propelling power meet at the same point longitudinally ? Chance work does not always miss its aim, although the model may not have been the best for speed, and the spars may have been stationed and proportioned as they have often been before, yet upon a scientific investigation the forces are found to act upon the principles of philosophy, which affords conclusive evidence that much more may be effected with model and spars agreeing, although neither in accordance with the philosophy of the science, than can be accomplished with the pressure or centre of displacement at one point, and the centre of the propelling power at another. Many builders suppose that it is sufficient for all practical purposes to find the centre of the absolute gravity, and to distribute the propelling power equally on each side of this point ; but this is an error, and is but too manifest, if we will but find the centre of displacement as well as that of the absolute gravity. I have never in a single instance in sea going vessels, known them to be located at the same point longitudinally. There are several methods of obtaining the absolute gravity of a ship at any line of flotation, the two simplest of which I shall endeavor to illustrate, that of comparative gravity and comparative bulk.

By comparative gravity we avoid those tedious calculations, and arrive with a good degree of certainty at the desirable result, there is no calculation rendered necessary that cannot be made from the model with more precision and in less time than from the draft. The model is an American invention and is a proud emblem of American genius. In order to ascertain the displacement of a ship from the model when immersed at the several waterlines, by comparative gravity, the model must be separated, and each section weighed in a balance, after noting the respective weights, a block must be cut five feet square and four feet long in the form of a cube by the scale upon which the model is made, the block will contain one hundred cubic feet, and assuming the section from which the block is taken to weigh five pounds and the block to weigh three ounces, we have the question simplified and reduced to a simple sum in the rule of three :—Thus, if 3 ounces contain 100 cubic feet, what number of cubic feet does 5 pounds contain ? The result or answer will be, two thousand six hundred and sixty-six and two-thirds ; this course when pursued with each section in the immersed part of the vessel, gives the entire contents in cubic feet, which being multiplied by 64, the weight in pounds of one

cubic foot of sea-water, gives the weight in pounds. It must however be remembered that the water in our rivers is not as salt as the ocean, and consequently does not weigh as much per cubic foot, which would materially affect the displacement by causing the vessel to draw more water than the calculation called for, but this may be remedied by weighing a foot of river water and making use of the result as a multiplier. When this method is adopted to obtain the displacement of a vessel of any description, there should be another model made as high as the greatest immersed line of flotation to which the thickness of the plank should be added, and through which no holes should be pierced. In order to obtain the displacement by comparative bulk, it will be necessary to make a box large enough to contain the immersed part of the model, or that part below the greatest immersed line of flotation, the box being made may be filled with fine dry sand, which upon being removed and kept apart from the surplus, must be reserved ; the part of the model already described may now be placed in the box, which being filled as before, will not contain as much as at first, by a quantity exactly equal to the bulk of the model or the bulk of fluid the vessel would displace, when loaded to the corresponding line of flotation, the sand may be measured in a box of 1, 2 or 3 inches square, the contents of which may be known in cubic feet by applying the scale upon which the model is made ; in this manner the bulk of sand may be reduced to cubic feet, the amount of which can be transposed into pounds as before described. This sum being doubled, we have the entire weight of the ship and cargo when immersed to the line of flotation at which the model was separated. When this method is resorted to there should be a separate model made, to which the thickness of the plank should be added. But although the ship would displace the quantity of fluid, and no more than the process already shown would call for, yet the line representing the line of flotation on the model, and the line of flotation on the ship, differ in form very materially. I will endeavor to illustrate this by assuming a ship to be partially filled with water until she comes down to any designated line of flotation, ascertain the displacement by the model as already described, and compare the form of the line of flotation as represented on the model with that of the ship, and the difference is at once apparent.

The builder assumes the water lines on his model to be the actual lines of flotation, without having sought for the centre of displacement, that he might know whether he is right or wrong. It will be rendered at once apparent, that if the centre of displacement is forward of the centre of the ship longitudinally, the line of flotation will be lower forward and higher aft, consequently sharper forward and fuller aft, and inversely when the centre of displacement is aft of the centre ; how important then to know the location of this point upon which the displaced bulk of fluid, were it congealed, would equilibriate, more particularly when it may be obtained so easy from the model. The actual line of flotation cannot be marked with precision without the aid of the hydrostatic balance, a correct calculation of the weight of timber in a ship cannot be made by averaging the weight per cubic foot. There is no table purporting to show the mean specific gravity of timber growing in this country that can be relied upon. I have known a difference of 7 per cent in the specific gravity of pieces of timber that grew almost beside each other, and the difference is much greater in timber coming from different sections of the country, and will range as high as 20 per cent. in timber known by the same name : white oak, for example, with the aid

of a hydrostatic balance, you may take but a chip from the log and obtain its specific gravity and its bulk or cubical contents, and measuring the contents of the log you may at once arrive at the weight. It is important that the builder should be able to tell what number of feet and inches his ship will draw before launching; in steam vessels and vessels of war, it is most essential. Assuming a frigate's displacement to be, when immersed to her limited or load line, 3,600 tons, assuming also the weight she is required to sustain in guns, ammunition, provision, fuel, men, &c. to be 1,700 tons, is it not plain that 1,900 tons is the limit for the weight of the hull and its appurtenances, and if the ship weighs more, she must displace more water, and consequently sink deeper in the water. It is not a little surprising that we see men that are considered scientific, making their calculations upon the strength, stress, and density of timber for practical purposes, from the tables of specific gravity found in European works, or from timber that grew many hundred miles from that they intend making use of. A location of more than two years in the swamps of the south have failed to satisfy me that any man can tell the density of timber from a table of specific gravities, it is not known at what age the tree must arrive, or whether it must arrive at a certain age before the capilary vessels discharge the air they contain, and are refilled with sap. It is in consequence of this change that we find young white oak timber will float, while the old timber will sink, particularly that growing south of Chesapeake Bay. My brief space precludes my following this subject farther. I will invite the attention of my audience to a part of the science of no less importance, but doubtless more interesting.

The principles upon which the velocity of vessels is consequent, are founded on the equilibrium of fluids, which leads to this conclusion, that to disturb the fluid as little as possible, and after having disturbed it, to restore it again to its former equilibrium, should be the object in view; in disturbing the fluid we decrease its density or diminish its buoyancy in the same ratio that the fluid is disturbed, this is owing to the globular form of the particles of which this element is composed, and to its extreme lubricity.

The prevailing opinion is, that the whole of the resistance arising from the collision of the immersed part of the ship against the particles of fluid in which she is immersed, is found on the anterior part of the ship; this opinion however has been long since rejected by scientific men; there are few if any vessels built that have none of this resistance on the posterior part of the hull, the lines of the after body of vessels generally built are not at all calculated to restore to an equilibrium the globular particles of fluid that are set in motion by the forward part of the vessel. A great portion of the resistance met by moving bodies in a fluid, arises from friction which is much greater than is generally supposed. Witness, if you please, its effect upon the surface of the ocean, it is the friction caused by the wind that propagates the waves, causing them to rise successively from base to summit; this friction which acts only upon the surface of the water, does not agitate the fluid to a great depth; this motion imparted to the fluid by the friction of the wind may be greatly diminished by pouring oil upon the surface, and comparative tranquility restored, which is a most convincing proof that vessels will sail faster having their bottoms sheathed with a smooth metallic substance, and will acquire a greater velocity than the ordinary vessel having the flexible fibres exposed to the action of the fluid, which paint cannot prevent. But if the

friction of the wind upon the water is sufficient to raise such weighty columns, the vertical oscillations of which produce such wondrous results, should we not by common consent agree, (apart from the experimental test) that to diminish the friction we increase the speed, and farther, is it not plain that if the fluid possesses an equilibrium when in a state of rest, it requires no more force to remove a given bulk near the anterior extremity than it would farther aft, and thus by easing the line at its extremity, it must of necessity be harder farther aft; consequently the resistance is diminished at the extremity and increased farther aft. But the whole story is not told; the friction is not diminished aft while it is increased forward, for on no formed line on the immersed part of a vessel does the fluid act, with as little friction as it does on lines forming the segment of a circle. The particles of the fluid being of a globular form, must of necessity partake of a whirling motion, consequently the form of the anterior part of the vessel designates not only the velocity of those particles, but their direction. The impulse imparted to the molecule of the fluid is in all cases at right angles with the adjacent parts of the body set in motion. This being the case, it is plain that the particles of fluid take different courses, or move in different directions, and it necessarily follows, that less force is required to impart a given velocity to a given number of molecules, when impelled at different angles, than when impelled at the same angle. It will be readily perceived that for a fluid to be in equilibrio when at rest, each particle of that fluid must be independent of the other, and the only tendency those particles have to move in any direction, is that imparted by its weight or absolute gravity, and, like all other bodies possessing matter, has a downward tendency. A column of fluid impelled from a state of rest by a moving body, and its particles all converging to a single point, by the laws governing its motions, must return with a reacting force, this is the case with all vessels having hollow lines on the anterior part; many persons have supposed that by thus equalizing the spaces for the retiring particles of fluid, by forming the lines as before described, that the ship must of necessity be sharp, and consequently unprofitable; but the lines forming the segment of a circle from the greatest transverse section to each extremity, can be adapted as well to the flat as to the sharp vessel, as well to the vessel having no dead rise as to the vessel having thirty degrees; it acts like a stiff batten to ease the hard places on the lines and fill out the slack ones. But I am told that hollow lines on the anterior part have been fairly tested, and have proved the most advantageous for speed; two ships have been built alike in other respects, the bow of the one being hollow, while the other carried the round line to its extremity, and the ship having the hollow line outsailed the other. However fair a test this may be supposed to be, I consider it no test at all; in the first place, the two ships, like all vessels of the ordinary models, their natural position not being known at any line of flotation, the evidence is most conclusive, that by diminishing the sustaining power forward, while the propelling power remained the same, would be testing the sparring of the ship as well as the model; on the ordinary model the spars would require to be shifted at every line of flotation, consequent upon the change in the position of the relative centre of gravity, which alters its position at every successive change in the amount of water displaced. Under such circumstances what security have we for testing the advantages or disadvantages of any model but by experiments upon a small scale; but we are told that models cannot be tested upon a small scale, that a series of such experiments have been in progress for years in the United States, and have failed to an-

swer the purpose designed. Of this fact I am well aware, having attentively watched their progress, and will show my audience the cause of such failures, and a continuation must and will inevitably follow, if based on other than first principles, as the models will plainly show they have been.

But the lines on the posterior part demands a share of our attention; perhaps no science known to man in the nineteenth century is so overburthened with ancient traditions as that of ship building; the hoary prejudices of our fathers have not grown obsolete: among the most prominent stands, that of the analogy in form, that should exist between the ship and the fish—a more fallacious argument in favour of the present method of building vessels for speed could not be adduced. I cannot discover any farther analogy in their required forms for velocity, than what may be derived from their both navigating the same element. A body partly immersed meets with much more resistance than one wholly immersed, (unless the lines forming the interior part forms an angle so acute that the resistance with a given velocity is less than the atmospheric pressure upon the surface of the fluid, which equals 2160 pounds to each spuare foot, for the following reasons, the body wholly immersed displaces a volume of fluid, the magnitude of which is precisely the same as that of the body itself, while the volume of fluid displaced by the floating body is just equal to the entire weight of that body, and it necessarily follows, that a body wholly immersed, a fish if you please, meets with the same resistance (regardless of the position, for every position is a natural one) while moving in a horizontal direction, and farther than this, while the amount of the absolute and lateral resistance may be calculated on the immersed body, it cannot with any degree of certainty be calculated upon the floating body, when in the form of a ship, modelled as they now are; for as soon as she is careened, her best position for speed is departed from, while the lateral resistance is diminished, and the absolute resistance augmented, and last though not least, the fish possesses within itself the elements of impulsion, a property the ship does not contain, inasmuch as the fish can escape the force of the waves, and the power of the wind, while the ship must contend with both; the resistance caused by the wave raised by the friction of the wind, although great, is not however, as much as is generally supposed; at the depth of thirty feet the fluid doubtless is at rest; it is this resistance that builders endeavour to counteract, when they rake both the stem and stern post, an error in practice, based on an error in judgment, upon the laws governing the motion of fluids; the equilibrium of fluids should teach us that the wave has not a progressive motion; when the fluid is set in motion by agitation, the mass is not transferred, neither is any part of it, the motion and that only is transferred, as will appear manifest upon observing any light body upon the surface. The appearance of progression is but a deception of the eye, caused by the form of the wave, and the mode of its oscillation; by close attention it will be seen that the fore part is always in the act of rising, and the hinder part in the act of falling, and thus the whole mass appears to roll onward, while each particle of water merely oscillates successively with a vertical ascent and decent; the cause of this reciprocating motion may be thus defined, when the surface of the water is unequally pressed, the columns sustaining the greatest pressure, sink below the original level; this pressure being communicated to the adjacent columns, cause them to rise above the level, and this lengthened column having no hydraulic pressure to sustain, it again falls, and in its descent acquires a velocity due to its height, and decends below the level, and in its turn communicates a pressure to the contiguous columns, thus by the particles to which

the original impulse was given, being alternately highest and lowest, a series of waves are formed. But if this free oscillation be prevented by shallow water, or rocks, so that the columns in deep water are not balanced by those in the shallow, they in consequence acquire a progressive motion towards the shallower water or rocks, and form breakers; hence the reason why waves always break against the shore, it matters not what is the direction of the wind. But it may be asked why it is that so much damage is done at sea, if the waves have not a progressive motion. It is doubtless owing to the strength of the wind; the side of the wave presented to the wind acquires a gentle slope, while the opposite, or lee side, is perpendicular when at its summit, and its own weight added to the power of the wind causes it to strike with such destructive force. But to return to the formation of the posterior part of the ship, it is important that the fluid should be restored to its former equilibrium in the shortest possible time; the loss of speed consequent upon a concave line, is greater than is generally acknowledged; on the concave, and on the straight line, a portion of the fluid is held by the vessel and carried along, and the portion thus held by the vessel serves as a kind of regulating medium to enable the fluid to regain its equilibrium; on the ordinary vessel or such vessels as are now built, the lines already described are found immediately above base line, while at the greatest immersed line of flotation, the lines will be found to be as much too full as they are too lean below.

Navigators have found that the fluid acts with more force upon the rudder about half way between the greatest immersed line of flotation and base line, than it does on other parts, and the reason will appear obvious, for it is only at that part of the rudder that the lines are formed so as to conduct the fluid with the least disturbance, consequently we are brought to the conclusion that the segment of a circle should be the form of the lines on the posterior, as well as on the anterior part of all vessels below the greatest immersed line of flotation, from the greatest transverse section, to each extremity. The whirling impulse imparted to the globular particles of fluid, show that they cannot be restored to their buoyancy by any sudden change of course. When the ship is careened about fifteen degrees from a vertical line, it alters the course of the fluid at the surface of the anterior as well as the posterior part of the ship, and when thus careened, the distance on the line of flotation from the greatest transverse section to the rudder being much shorter on the windward than on the leeward side, it follows as a consequence that the fluid acts with much greater force upon the windward side of the rudder than it does upon the leeward side. It must have been quite apparent to every man who has thought upon the subject, that as the vessel careens, the two lines of flotation that were alike when the vessel was upright, now have their forms altered, the one becoming much easier, while the other becomes much harder. It must follow that the pressure consequent upon the current formed by the moving vessel, on the two sides of the rudder, being unequal when the helm is midships, that the vessel is brought to the wind, and to avoid which the helmsman must keep his helm up until the two forces are equal. Careening a vessel of the ordinary model, has the same effect upon the steering qualities that it would have to move the stern post one, two, or three feet aside from the centre of the vessel, terminating all the lines there, and then sailing her in an upright position. We do not find that when vessels are scudding or sailing before the wind, that they require the helm on one side more than the other, the reason is obvious; the pressure on the two sides of the rudder is equal, hence the reason why mariners complain of vessels steering

bad before the wind. They veer from their course until they receive the wind from the quarter; this causes them to careen, and as soon as careened the fluid ceases to act with as much force on the leeward side, and acts with increased force on the windward side; consequently she is steady for the moment, but as soon as the helmsman brings her to her course, she performs the same freaks again.

A more convincing proof could not be adduced, that the vessels spars are not in accordance with the peculiarities of the model, than may be seen in the ship steering as just described when sailing before the wind. Is it not plain that when there is a difference of a number of feet in the form of the two lines of flotation, the windward and leeward lines, and that near their terminations, that it effects the steering qualities more than every thing beside. I have known a difference of eight feet as far aft as the fashion piece in those two lines of flotation, while the difference was not more than two feet at the greatest transverse section, and this discrepancy on what is supposed to be one of our finest *packet ships* sailing out of the port of New-York; and I very much doubt whether there can be one found with less than six feet of difference when immersed to their greatest immersed line of flotation. And I have yet to learn that any better reason can be assigned of the continuation of this glaring error than that of precedent. It must be remembered that with the wind blowing from any other point than directly aft, it acts on the whole length of the vessel, this being the case, and the lateral resistance being equalized, the vessel could have no tendency to veer from her course, the cause being removed, the effects must cease. I have no hesitation in saying, that were the lines of flotation of such form as I have described, and the spars arranged as I have yet to show they should be, the helm might be lashed midships a whole watch if you please, and the vessel would be true to her course; this can never be the case in the ordinary modelled vessel, let the spars be stationed where, or proportioned as they may be, for the following reasons: the two lines of flotation being of a different form when the vessel is careened, and subject to a still greater or less alteration in their form as the vessel is careened more or less, the helm must be constantly attended to, for upon the slightest variation in the force of the wind, a corresponding change takes place in the form of the two lines of flotation, which is at once felt at the helm; the truth of this assertion will doubtless be conceded by every mariner.

Another cause contributes in some measure to effect the same end: the stern post of many of our ships is quite large enough for a rudder were it hung on pintles, and the ship could be steered with more ease than they now can, with a rudder three times the size; the stern post of all vessels should be inside and not out side of the vessel; a sufficiency of wood to caulk the wood ends against is quite enough, the remainder be it what it may should be inside, and farther than this, the lines should terminate at the after edge of the stern post, of course the siding size of the stern post would be more than the ordinary post, or more than the size of the keel, but above the greatest immersed line of flotation, it would not require to be carried with the line; the advantages of strength alone should be a sufficient inducement to cause every builder to adopt this method. A stern post altogether outside of the vessel cannot be secured sufficiently with the fore and aft fastenings, to resist successfully the surges against the rudder, and the consequence is that sometimes it is started from its place. With a stern post such as I have described, the rudder may be reduced. A batten bent to the form of the line at any given height, and parallel to that line, the after end intersecting the

after edge of the stern post, will show how much power is lost to the rudder, and not only lost, but it acts a conspicuous part in diminishing the power of the contiguous volumes of fluid farther aft, causing them to strike more obliquely, and consequently with less force. This in connection with the large buttocks which many of our ships have, is the cause of their bad steering qualities.

Were the method above alluded to, adopted, we should not see ships with studding sails set on both sides, veer so much as to make them shake, while the helmsman has his helm hard over both ways. The attraction the particles of fluid possess for a hollow line, or for a line forming an irregular curve, is much more than many persons have supposed. The result of experiments have clearly shown that the resistance on the posterior part commences, (or the greatest portion,) at the first break in the line, from the gentle curve to that of straight, and a portion of the fluid is conveyed, as much at least, as would continue the curve fair; the consequence is that the column of fluid in its course with the vessel, disturbs all the adjacent columns, that were nearly restored to their equilibrium. At the surface of the water, or upon the greatest immersed line of flotation, we find the disturbance to be somewhat farther aft than it is below; here we find the break in the line commencing but a few feet forward of the end of the transom, and abaft that hard spot on the line, there is a counter current formed, and all the adjacent particles of fluid are carried within this vortex, while the two currents, or the current opposite to the vessel's course may be seen a number of feet aft of the rudder terminating to a point from the two sides. This reacting force, consequent upon the continued disturbance of the adjacent volumes of fluid on the posterior, as well as the anterior part of the vessel, may be seen in shallow water, without careening the vessel. Witness its power in a canal, in retarding the progress of the vessel; the bulk of the fluid being small, the reaction is doubled when the boat is forced beyond a moderate speed; the cavity made by the passing vessel forces the fluid in a disturbed state upon the shore, from whence it is impelled by a force generating the undulations seen at the surface, not at all calculated to restore the fluid to its former buoyant smoothness; those volumes, thus impelled from the shore, fall upon other volumes disturbed by the vessel in her onward course; the undulations are thus communicated to the whole mass, as may be seen, following successively in the vessel's wake; whereas had the water been of a greater depth, and the shore at a greater distance from the vessel, the volumes of fluid forced assunder from the bows of the vessel, would have fallen upon other volumes, yielding in proportion to the force with which they came, and those falling upon others with diminished force; thus the fluid next to the vessel which was disturbed first would be restored to its equilibrium first, but in the canal that disturbed first is restored last, in consequence of this reaction from the shore; and the greater the power applied to force the vessel beyond the ordinary speed, the greater this reaction, and as a consequence the speed of the vessel is diminished instead of increased.

I will now endeavor to illustrate the last but not the least important section of my lecture, that of sparring vessels. It is an acknowledged axiom in mechanics, that when force is applied at different points of a moving body, whether parallel to the course of that body, or perpendicular to that course, it should be so distributed that its effect would be the same as if concentrated at a single point. How near this principle approximates to that up-

on which our ships are sparred may be seen, when compared with the stereotyped editions of the dimensions and stations of spars corresponding to ships of certain principal dimensions, both in our merchant marine, and in the United States Navy, without any regard whatever to the peculiarities of the model of the ship; the consequences are legibly stamped on every ship; the sequel is soon drawn; our merchant ships which should now be the fastest sailing vessels on the globe, are no better sailers than they were some twenty years gone by, while our white winged messengers of war float but to display the discrepancies in the art, and destined ever to remain so, while hereditary principles occupy a station so exalted in the councils of the nation.

Is it not plain, and will it not appear evident to the thinking man, that were a ship of the ordinary model sparred by the usual modes, cut transversely into three sections, the longitudinal ratio of each having the same relation to the other that the several masts have, that the leverage would be found to be much greater on the forward and after, than on the midship section. I will endeavor to illustrate farther by assuming proportions that will be found upon an investigation to approximate nearer the truth than the casual observer would be likely to suppose.

First, assuming the buoyancy on the forward section, to equal 75 per cent. of the midship section, and the buoyancy of the after section to equal 35 per cent of the midship section, does it not follow that the leverage of those sections should bear the same ratio to the midship section that the buoyancy bears, and I would ask the builders of this city, in all candour, if the leverage does not often exceed 90 per cent. on the forward section, while the buoyancy scarce equals 60, and the leverage on the after section often exceeds 50, while the buoyancy does not amount to 30 per cent.

In sparring ships of the ordinary model, it is requisite that a medium line of flotation should be adopted, upon which to base the necessary calculations, but if the ship is built by such model as has been already described, it will make no difference which line of flotation is adopted; the centres of the relative and absolute gravity of the immersed portion of the ship being in line, perpendicularly, either from base line or from the greatest immersed line of flotation, it necessarily follows that the spars will be adopted to every line of flotation, provided the ship is brought to her natural position, at every successive change in the line of flotation; the centre of the relative gravity should be marked on the model of every vessel, it being the fulcrum upon which the two powers should be equally balanced longitudinally. The great secret in sparring vessels, consists chiefly in finding the proper stations for the masts and their corresponding lengths. To find the stations of a ship's masts it is necessary that a batten should be made of a mean size and density, the length of which should correspond with the length of the model at the line of flotation to which the spars are to be adapted, transferring the centre of relative gravity from the model to the batten; in order to expedite the operation, the ordinary stations of the masts may be marked on the batten, at which stations the breadths of the model at the designated line of flotation should also be taken, when weights bearing the same ratio to each other, that the breadths bear, may be suspended at the stations thus marked, and applying a fulcrum to the mark representing the centre of the relative gravity, in a transverse position; the result will be that the anterior part has the preponderance, and it is found necessary to alter the stations of the weights, commencing with that of the one representing the main mast, which

should be moved aft when it will be found necessary to diminish it in the same ratio, that the breadth has decreased from that of the former station; the weights representing the fore and mizzen mast may be moved in the same manner; they also must be made to correspond with their respective breadths at their new stations; apply the fulcrum again, and continue the operation already described until the weights are equally balanced on each side of the centre of the relative gravity, and at the same time bear the same proportion to each orher that their respective breadths bear at the several stations. This being done, we have the stations of the mast and their relative lengths.

It is a well known theorem demonstrated by mathematical science, that when several forces are applied to a floating body (the equilibrium of which is stable) in a perpendicular line, and each bearing a ratio proportionate to its point of elevation, the integral forces would have the same effect when elevated at a single point, that point bearing the same ratio to the whole elevated distance that the several parts bore at their respective heights; this being the case, it necessarily follows that the smaller spars, yards, &c., should bear the same proportion on the several masts; consequently it is only necessary to adopt a length for the main mast, main top mast, and main yard, proportionate to the amount of stability, or to the space between the centre of the absolute gravity and the centre of displacement, which may be readily obtained. It may be necessary for the purposes of convenience to alter the station of one of the masts; for example, it may not be convenient to have the mizzen mast so far forward as this method would seem to require that it should be; to obviate this, we have but to shift the main mast farther forward, or both the main and fore mast, remembering also to make the weights correspond with their respective widths; having done this, the mizzen mast may be be brought forward until the ratio and station agrees as before.

Having determined the stations of the masts and the length of the main-mast, the length of the fore and mizzen-mast should bear the same proportion to the length of the main-mast, that their respective breadths bear to the breadth at which the main-mast is stationed.

Having obtained the length of the main top-mast, it will be necessary to get the ratio it bears to the length of the main-mast between the line of flotation and the tressletrees, proportioning the fore and mizzen top-masts in the same manner to their respective masts; proceed with the top gallant-masts in the same manner proportioning them to the top-masts as the top-masts were to the lower masts; the royal-masts may be proportioned in the same manner.

The length of the main-yard being also determined, we will first find the ratio it bears to the length of the main-mast, and proportion the fore and cross-jack yards to the fore and mizzen-masts in the same manner; the topsail-yards should be to the lower yards what the top-mast is to the lower mast, and the top-gallant and royal-yards the same to their respective yards below.

As the head and other fore and aft sails are principally advantageous only in working the ship, I have not considered it necessary to annex them to the system here set forth, apart from their having an influence on the ship somewhat different from that generally assumed; the length of the bowsprit and jibbooms, &c., should be governed by the steering qualities of the ship, and in no case should the sail upon those spars be calculated with the propelling power of the ship; and whenever this mode is adopted, error and disappointment is the inevitable consequence.

It may be necessary that I should give my views upon the rake of the masts or their inclination from a vertical line; this is a matter of small mo-

ment in the ship, farther than this, that in raking them aft, their stations should be moved forward; and to do this correctly, the whole length of the masts from the line of flotation to the royal mast-head must be known, and of this length take the same proportion that the length of the top-mast bore to the length of the mast between the line of flotation and the tressletrees; set up this length from the line of immersion, and square the same down to its termination on said line, or the amount of rake per foot being determined, it will only be necessary to add as many times the amount of rake per foot, together, as there are feet in the proportion already named, shifting the masts that distance forward; this method is applicable to all square rigged vessels.

With regard to the rake of schooners' masts, there are various opinions, and perhaps among them all there is none more erroneous than that upon which the practice is based, of raking the main-mast as much or more than the fore-mast, the manifest effect of which is to counteract all the lifting power obtained forward; the quantity of sail forward having the preponderance, it is found that the bow is depressed when it blows heavy, from whence originated the idea that a vessel might be run under or completely submerged forward. I readily admit that were a vessel overburthened forward, and having a powerful lifting lever aft, (which the raking main-mast undoubtedly is,) such a catastrophe might occur, but with the sustaining power equalized and the propelling power in accordance, it is impossible.

But perhaps I may be told that a ship's spars thus arranged, would tend to disparage the beauty of the ship. To those who may have had their visions so completely familiarized with the present system, and their taste so far corrupted by the mode as at present practised, that *beauty* and incongruity are synomymous terms; to such let me repeat, that beauty consists but in *fitness* for the purpose, and *proportion* to effect the object *designed.* Before I conclude my remarks upon sparring vessels by their models, I will only add that the preponderance of sail on the anterior part of all ships, is intended to counteract a difficulty aft, which builders and navigators have sought in vain in the ærial regions to find; the present mode of sparring, serves as a prop to support the manifest errors in modelling; hence we find paliative measures adopted, to effect what experience cannot prevent. If experience is the grand palladium in the science of ship building, why has it not done more in this commercial diatatrix of maratime enterprise, in the last quarter of a century, having had a practice without a parallel in commercial history.

Science has always had its opposers as well as its supporters, and this science perhaps more than any other; but may we not cherish the hope that the day is not far distant, when the zeal of its opposers must dwindle into insignificance, when ship building shall not be regarded, as a *dark, mysterious,* and but half developed system, but as one of the most brilliant, harmonious, and beautiful of all systems, rising like a new Cythera from the enchanted wave. Were our ships built upon scientific principles, we should not so often hear the direful tidings that is now wafted on every breeze, of the wreck of that surge beaten bark, having been swallowed up amid the mountain crested billows of that dark abyss! that heart-rending news would not so often break upon our ear, that our friend or kindred has found a winding sheet beneath that dark blue wave. The silent footfall of time has brought us to the threshhold of an era, in which the material of construction must soon be partially changed, and if we would successfully compete with those whose interest leads them to a scientific research, we must build vessels upon such principles as will ensure their success.

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